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Collembola of Southwestern North Dakota: Species Composition and Habitat Distribution

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ABSTRACT — One hundred sites representing 17 habitat types occurring in southwestern North Dakota were examined for insects of the order Collembola (springtails). Seventy-six kinds were obtained, eight of which could not be identified to an existing species and may represent undescribed species. Of the 68 identified species, all but one represent first records for North Dakota. *Odontella bayeri*, a european species, is recorded for the first time from the North American continent, and *Onychiurus affinis*, previously known from Canada, is recorded for the first time from the United States. *Tullbergia mala* exhibited the widest ecological amplitude, being found in all but one of the habitats and in two-thirds of the sites. Twenty-one species occurred only in forest habitats and three species occurred only in grassland habitats. The colembolan fauna is predominantly a forest-adapted one, some species of which have spread into grasslands and other non-forest habitats.

Studies of soil ecosystems have emphasized the importance of both physical characteristics (texture, porosity, etc.) and dynamic processes, such as energy flow and nutrient cycling, in determining the character of the community. The biota is intimately involved in creating these characteristics as well as responding to them. Various estimates have been made of the relative significance of different groups of soil fauna in this interaction. Comminution of dead plant material is ascribed mainly to the larger invertebrates such as earthworms, isopods, and insect larvae (Wood 1966); their activities are instrumental in determining soil morphology. In terms of energy, MacFadyen (1963) estimated that together the Acari, Collembola, Enchytraeidae, and Nematoda accounted for less than 10% of the energy flow in a grazed meadow. However, he emphasized their likely role in the dispersion of microbial spores and the stimulation of microbial activity. In environments where larger invertebrates are relatively scarce, microarthropods may assume greater importance. The soils of southwestern North Dakota, particularly those of the grasslands, are subjected to moisture limitation and relatively great temperature fluctuations, compared to areas in which the soil climate is moderated by higher rainfall and more abundant vegetation. The Collembola (springtails) and other microarthropods can be viewed as a necessary link in the decomposition sequence; in their absence, nutrient cycling might be appreciably slower.

The purpose of this study was to determine what species of collembolans occurred in southwestern North Dakota and which habitats were occupied by

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each species. Our examination of the collembolan fauna of southwestern North Dakota was initiated, in part, in response to the recent expansion of coal surface mining and oil and gas exploration in the area. Reclamation concerns have largely centered around vegetation as a significant indicator of land condition. However, less obvious factors, such as soil fauna, are also recognized as being important in the long term function of the ecosystem.

METHODS

The research was designed to intensively study 100 sites in southwestern North Dakota, an area consisting of all counties (14) south and west of the Missouri River plus McLean County east of the river (Fig. 1). One site was allocated (up to a maximum of 11) for each approximately 50,000 hectares of area in a county. Seventeen habitat types characteristic of the project area were identified. The number of sample sites for each habitat type was based in part upon the frequency with which that type occurred in the overall project area. A minimum of two sites for a given habitat was selected, while the maximum number of sites for a single habitat type was 17. These sites were distributed primarily on the basis of areal extent of that site type within each of the 15 counties (Fig. 1). Some habitat types were of limited occurrence, e.g., coniferous forest, river sandbar; others, e.g., gentle slopes, roadside ditch, etc., could be found in all counties. The selection of habitat types for a given county was somewhat arbitrary because distribution within the overall project area also had to be considered. Where only two or three sites for a given habitat were utilized, they

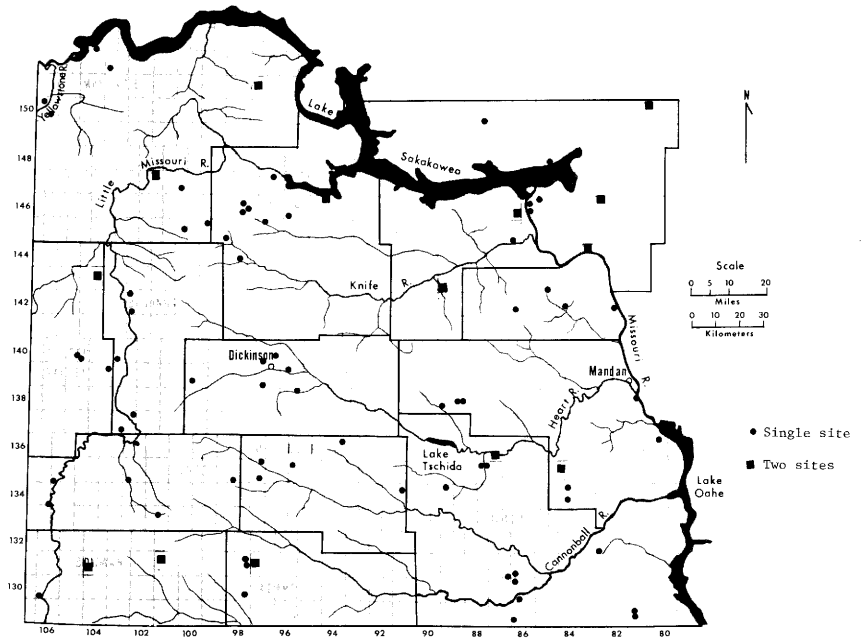

Fig. 1 Locations of study sites in southwestern North Dakota.

were located in non-adjacent counties so as to provide for geographic variation. In some instances, two sites (representing different habitats) were chosen within the same quarter section of land.

Field work was conducted between 2 July and 1 September 1976 and 14 and 23 May 1977. We sought to examine the fauna present during the summer dry period and that present during spring, when more moist soil conditions were the norm, since some species might occur at one time of the year but be absent at another. However, the period from mid-1976 to mid-1977 was one of nearly continuous drought for the area; autumn rainfall, winter snowfall, and spring rainfall were below normal. Some sites appeared to be drier in May 1977 than they had been the previous summer.

At each site soil samples were taken from five areas selected at random within a 100-m^2 quadrat. Subsamples were taken from each of the five samples as follows: litter, 0-5 cm, 5-15 cm, and 15-25 cm. Soil was dug by a spade (an auger proved unsuitable for dry grassland soils) to a depth of about 25 cm, and from the appropriate midpoint of each depth level a 50 cm^3 sample of soil sufficient to fill a 5-cm diameter sample container was collected. Litter samples varied in size, depending on the thickness of the litter above the soil sampled. Each subsample was placed in a small plastic bag, labeled with site number, sample number and depth, sealed, and stored in a cooler until transported back to the building where the extracting equipment was set up. From the two collection periods a total of 3,840 samples of litter or soil was collected; litter samples were not present on some sites and a few bottom samples could not be obtained because of hard claypans.

The extraction apparatus was a modified Tullgren funnel design based upon that of Merchant and Crossley (1970). The apparatus was designed to process 40 samples at a time. Samples were extracted for a period of 22 hours and the organisms were collected in 4 or 6 dram vials of 70% ethyl alcohol attached to the ends of the funnels by masking tape. One apparatus was operated in 1976; two units were used in 1977.

The organisms collected in ethanol were sorted and counted under a dissecting microscope. The collembolans were cleared for 24 hours in Marc Andre I fluid (distilled water, 30 ml; chloral hydrate, 40 g; glacial acetic acid, 30 ml) according to the method of K. A. Christiansen, Grinnell College (pers. commun.). They were then mounted on slides in Hoyer's medium (distilled water, 50 ml; gum arabic, 30 g; chloral hydrate, 200 g; glycerine, 20 g). Specimens were identified to species when possible, originally using the keys of Maynard (1951) and Mills (1934). Final identifications were made with the keys in the manuscript version of Christiansen and Bellinger (1980) and representative specimens were verified by K. A. Christiansen. Any errors in assigning individual specimens to species are our own.

DESCRIPTION OF THE STUDY AREA

Southwestern North Dakota is an area of gently rolling to dissected topography bordered on the north and east by the Missouri River. A narrow region south and west of the Missouri River is covered by a thin later of glacial drift. The remainder of the region is an unglaciated plateau of Cretaceous and

Tertiary shale, sandstone, and siltstone, well dissected by integrated drainage. The Little Missouri River bisects this plateau from south to north, with badlands along its valley. Elevations range from 488 m at the Missouri River to 1069 m at White Butte near the southwestern corner of the region.

The climate of southwestern North Dakota is of the dry, mid-latitude steppe type (BSK). The mean annual temperature is about 5°C. The mean annual precipitation is about 38 cm, most of which falls in the spring and early summer months. Evaporation is much greater than precipitation.

This region of the state is characterized by mixed grass prairie on the uplands and deciduous hardwood forests fringing the streams. An uplands deciduous hardwood forest occurs on the Killdeer Mountains and on certain buttes in other parts of the region, especially towards the northeastern part. Coniferous forests are found primarily in the valley of the Little Missouri River.

Sampling site types could be broadly categorized as grasslands, forest, and miscellaneous. Native grasslands included prairie (steep slopes and gentle slopes), shrubby grasslands, wet meadows, and claypans. Saline lowlands, seeded grasslands, and roadside ditches were examples of grasslands that might have some native vegetation present but that generally had received some form of disturbance. Forested areas were subdivided into upland deciduous, wooded draws, riverbottom, coniferous, and shelterbelts-farmsteads. In the miscellaneous category were included stripmine spoils, badlands, river sandbars, and cultivated fields.

Grasslands

1) Ridge tops and steep slopes of native grassland tended to be drier than gently sloping grasslands. This and the following two types were generally unbroken, sandy to clay soils utilized as cattle range. Characteristic vegetation included blue grama (*Bouteloua gracilis*), green needlegrass (*Stipa viridula*), and needle-and-thread grass (*Stipa comata*).
2) Gentle slopes included areas having up to 20° slope, but were typically level to 10° slope. On these silty loams and silty clay loams grew blue grama, green needlegrass, prairie junegrass (*Koeleria cristata*), and wheatgrasses (*Agropyron* spp).
3) Shrubby grasslands were chosen as having appreciable but less than 50% shrub cover. The level to gently sloping terrain included soils ranging from silty loam to clay. Two sites were characterized by sagebrush (*Artemisia cana*), two a mixture of sagebrush and wolfberry (*Symphoricarpos occidentalis*), and one a mixture of wolfberry and prairie rose (*Rosa arkansana*), with associated grasses.
4) Wet meadow soils were silty clay or clay and were generally saturated and anoxic slightly below the surface. Sedges and rushes were the dominant vegetations which also included wetland grasses such as reed-canary grass (*Phalaris arundinacea*), sloughgrass (*Beckmannia syzigachne*), and prairie cordgrass (*Spartina pectinata*).
5) Claypans were characterized by impermeable clay soils, sometimes overlain in patches by a thin layer of a more permeable soil. The panspots were nearly barren, supporting some muhly (*Muhlenbergia* sp.), prickly pear (*Opuntia polycantha*), gumweed (*Grindelia squarrosa*), and lichen.
6) Saline lowlands or "alkali flats" occur on clay and silty clay soils where the drainage pattern results in the deposition of large amounts of salts, often forming a crust as the soil dries. One site was a pasture area dominated by saltgrass (*Distichlis stricta*) and also including weedy species such as wild barley (*Hordeum jubatum*) and gumweed. The other two sites, on former cropland, supported a sparse cover of weedy annuals: wild barley, goosefoot (*Chenopodium* spp.), and burning bush (*Kochia scoparia*).
7) Seeded grasslands were on gently sloping terrain with silty to clay loam soils. One site was regularly cut for hay, the others utilized as range. Crested wheatgrass (*Agropyron cristata*),

other wheatgrasses, brome (*Bromus* spp.), alfalfa (*Medicago sativa*), and sweet clover (*Melilotus* spp.) were typical.

8) Roadside ditches resembled seeded grasslands in their vegetation patterns; wheatgrasses, brome, alfalfa, and annual weeds were common. Soils were silty to clay loams.

Forests

9) Upland deciduous forests are relatively large wooded areas on hill slopes, ranging from humus-rich sites with dense canopy to more open sites with appreciable herbaceous cover. Canopy dominants included paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), bur oak (*Quercus macrocarpa*), and/or green ash (*Fraxinus pennsylvanica* var. *subintegerrima*).

10) Wooded draws are the most characteristic "forest" pattern in southwestern North Dakota, particularly as one proceeds farther west. They occur on slopes just above watercourses, but the extent of forested area is limited to a relatively short distance above the stream. Canopy cover, leaf litter and humus content were typically less, and grass cover greater, than on upland deciduous sites. Grazing had occurred on all sties, contributing to their comparatively open character. Green ash, quaking aspen, bur oak, and American elm (*Ulmus americana*) comprised the canopy.

11) Riverbottom forests were located on level floodplains. Cottonwood (*Populus deltoides*) and green ash were typical canopy trees; shrubs were sparse, but herbs were common on the alluvial silts and sands of these sites.

12) Coniferous forest sites were highly variable in degree of cover, but all were on dry, usually north-facing slopes. Rocky Mountain juniper (*Juniperus scopulorum*), ponderosa pine (*Pinus ponderosa*), or limber pine (*Pinus flexilis*) was the dominant tree.

13) Shelterbelts and farmsteads are rows of trees planted between cultivated fields and around the farm buildings as wind protection. Siberian elm (*Ulmus pumila*) and green ash were most common; grass and annual weeds made up the ground cover on these sandy loam to silty clay loam soils.

Miscellaneous

14) Of the two stripmine spoils sites, one had been leveled and covered with about 15 cm of brown clay loam topsoil; the other was on steeply sloping piles of unconsolidated spoil material. The former site had been planted with crested wheatgrass, brome, slender wheatgrass, and sweet clover; the latter had been planted to trees, Siberian elm, Russian olive (*Elaeagnus angustifolia*), plus grasses and herbs.

15) Badlands sites were steeply sloping and sparsely vegetated clays. Rabbitbrush (*Chrysothamnus graveolens*) and saltbush (*Atriplex confertifolia*) grew from crevices in the eroded buttes; catsfoot (*Antennaria* sp.), gumweed, saltgrass, and other grasses were occasional on terraced areas.

16) Two river sandbars were selected, one a sloping area ranging from bare sand to young willows (*Salix* sp.) and cottonwoods, and the other a level area having clumps of horsetail (*Equisetum* sp.) and scattered young willow.

17) Cultivated fields sampled were generally in summer fallow. Vegetative cover on these silt loam and clay loam soils consisted of scattered annual weeds.

RESULTS AND DISCUSSION

Species collected

A total of 9778 specimens of collembolans representing six families was collected (Table 1). The greatest number of specimens, 32% of those identified to family, was of the family Hypogastruridae. Two other families, Isotomidae and Onychiuridae, were nearly as abundant. The collembolans collected represented 76 species (Table 2). Only one species, *Onychiurus reluctus*, has previously been recorded for North Dakota.

Odontella bayeri is recorded from the North American continent for the first time. This is surprising considering that this species was found in more than

Table 1. Number of collembolans collected from southwestern North Dakota by Tullgren extraction process.

Family	Number of Specimens	Percent of Total
Neelidae	2	—
Sminthuridae	113	1
Onychiuridae	2,237	23
Hypogastruridae	3,139	32
Isotomidae	2,907	30
Entomobryidae	334	3
*Unidentified	1,046	11
Total	9,778	100

*Also includes specimens damaged or lost in processing.

one-third of the sites and in 14 of the 17 habitats. The collection of *Onychiurus affinis* is the first record from the United States, although previously recorded in North America from Canada. Eight kinds could not be identified to any existing species and probably represent undescribed species. Four species (*Willemia dubia, Xenylla duchesnea, Isotomodes fiscus*, and *Proisotoma dubia*) are each recorded for only the second time. *Xenylla duchesnea* and *I. fiscus* are common and widely distributed in the region, being found in approximately one-fifth of the sites and one-half of the habitat types. Two others, *Tullbergia collis* and *T. ruseki*, have been found for the first time outside the states from which were originally described, California and Indiana respectively. *Tullbergia ruseki* was common and widespread in the region. *Tullbergia hades*, previously known only from caves in Iowa and Minnesota, is recorded as living in surface soils for the first time. The collections of *Cryptopygus exilis* constitute the second record for North America, the only other record coming from Michigan.

Habitat distribution

While a few of the 76 species collected were found over a wide variety of habitats, most species showed affinities for one or several habitat types, and related habitat types tended to have similar species number and composition. The grassland fauna was generally low in species number (Table 3). For one grassland and one claypan site, no collembolans were recorded from either the summer or spring sampling. Nearly all species found in grassland sites were also found in one or more of the forested sites, while there were many species found in forested sites that were absent from grasslands. However, *Friesea mirabilis* was found only in gently sloping native grasslands, claypans, and a badlands site (Table 2), suggesting a definite preference for dry sites or an inability to successfully compete with other species in more moist sites. *Entomobrya assuta* was recorded only from two native grasslands and one cultivated field; *E. sabulicola* was collected only at a single claypan site. Two specimens of *Seira bipunctata* were collected, both from one shrubby grassland site. *Willemia similis* was recorded from two native grasslands and a roadside ditch.

Species that were occasionally collected from woodland sites but that were found more often in drier sites included *Onychiurus reluctus, Odontella armata,*

O. bayeri, Anurophorus septentrionalis, Isotomodes fiscus, and *Folsomia decaxiopthalma. Cryptopygus thermophilia* was found in only four sites: a steeply sloping native grassland, roadside ditch, wooded draw, and cultivated field. *Willowsia buski* occurred in two native grasslands, a claypan and one deciduous forest. A cosmopolitan species that was common in both grasslands and forests was *Tullbergia mala. Folsomides americanus* was well represented in grasslands also, but was nearly ubiquitous (28/32) in wooded sites.

Disturbed land habitats (seeded grassland, roadside ditch, shelterbelt, stripmine spoils, and cultivated fields) show reduced faunas when compared to nearby natural habitats. No unique species were associated with such habitats.

Of the native grasslands studied, the ridge and steep slope prairies, gentle slope prairies, and shrubby grasslands showed similar species composition (Table 2). Eighteen species were found in only one of the three habitats, but in none of those cases was the species found in more than two sites of that habitat type. This suggests that their absence from the other native sites was related to their rarity rather than to a preference among those three habitats. Ten species occurred in two of the three habitat types, another 11 species were present in at least one site from each of the three. In comparing steep and gentle slopes, no differences are evident; of species that appeared in one but not the other habitat, none was present at more than three sites. Species occurring in both of these habitat types were often present in a similar proportion of the habitats, for example, *Tullbergia mala, Odontella armata,* and *Anurophorus septentrionalis* (Table 2).

The three claypan sites were quite poor in species (Tables 2 and 3). *Tullbergia mala, T. pacifica* and *Odontella bayeri*, all widespread species, were among those found at one claypan site. *Entomobrya sabulicola*, a species restricted to arid habitats (K. A. Christiansen pers. commun.), was also found there. At a second claypan site, only two species (*Willowsia buski* and *Friesea mirabilis*) were found, and the third claypan site had no collembolans.

Saline lowlands, similarly, had the fewest species (four). In two of the sites this may have been influenced by cultivation in recent years; however, those two sites lacked the species that were common in our cultivated field samples. The other site had been in pasture for some time. All three were wet. *Tullbergia pacifica* and *Odontella armata* were each found in two of the three sites, though not the same two. *Friesea cera* and *Anurophorus septentrionalis* occurred in the saline pasture site. All four of these species were present both in other grasslands and in woodlands, *O. armata* and *A. septentrionalis* being more common in grasslands while the other two species were more frequent in woodlands. No species was restricted entirely to saline sites. The extremely common *Tullbergia mala* was found in at least one example of every habitat type *except* saline lowland.

Wet meadows were an exception to the general character of grassland sites. Most of their species were cosmopolitan or were otherwise found primarily in forest sites. *Friesea pentacantha* showed a definite affinity for wet habitats, occurring in three of the four wet meadow si ained of the riverbottom forest sites; *Isotomurus palustroides* was recorded from one wet meadow and one riverbottom forest (Table 2). While the number of species found

in wet meadows, 20, did not differ appreciably from the number found in prairie grasslands or shrubby grasslands (Table 2), a difference is apparent in the distribution of those species among families. The wet meadows have a higher proportion of sminthurid species and a lower proportion of hypogastrurid species compared to other grassland habitats. The dense vegetation of the wet meadow provides an excellent habitat for Sminthuridae, which tend to be concentrated in

TABLE 2. Frequency of occurrence of Collembola species by habitat type.

HABITAT	GRASSLANDS								FOREST					MISCELLANEOUS						
SPECIES	Ridge & Steep Slope	Gentle Slope	Shrubby Grassland	Claypan	Saline Lowland	Wet Meadow	Seeded Grassland	Roadside Ditch	Upland Deciduous Forest	Wooded Draw Forest	Riverbottom Forest	Coniferous Forest	Shelterbelt, Farmstead	Strip mine Spoils	Badlands	River Sandbar	Cultivated Field	Total number of sites occupied	Number of habitat types occupied
Number of Sites	13	17	5	3	3	4	4	4	9	8	4	6	5	2	4	2	7	100	17
HYPOGASTRURIDAE																			
Anurida pygmaea (Börner)	–	–	20*	–	–	25	–	–	67	38	25	–	–	–	–	–	–	12	5
Friesea cera C. & B.	15	–	–	–	33	–	–	–	44	–	–	17	–	–	25	50	–	10	6
F. mirabilis (Tullberg)	–	12	–	67	–	–	–	–	–	–	–	–	–	–	25	–	–	5	3
F. pentacantha Mills	–	–	–	–	–	75	–	–	–	–	25	–	–	–	–	–	–	4	2
F. sp. #1	8	–	–	–	–	–	–	–	–	25	–	–	–	–	–	–	–	5	3
Hypogastrura nivicola (Fitch)	–	6	–	–	–	50	–	50	–	13	–	40	–	50	–	–	29	9	6
H. succinea Gisin	–	–	–	–	–	–	–	–	–	25	–	33	20	–	–	–	14	6	4
H. sp. #1	–	–	–	–	–	–	25	–	–	–	–	–	–	–	–	–	–	3	2
Neanura muscorum (Templeton)	–	–	–	–	–	–	–	–	11	–	–	33	–	–	–	–	–	1	1
Odontella armata (Axelson)	46	47	60	–	67	–	25	25	56	25	50	33	20	50	50	–	14	37	14
O. bayeri (Kseneman)	38	12	40	33	–	–	–	75	22	38	–	17	20	100	50	–	57	28	12
Pseudachorutes subcrassoides Mills	15	6	–	–	–	–	25	–	100	50	50	17	20	–	–	50	–	22	9
Willemia denisi Mills	–	6	–	–	–	–	–	–	56	13	25	–	–	–	–	–	–	8	4
W. dubia C. & B.	–	–	–	–	–	–	–	–	–	–	–	17	–	–	–	–	–	1	1
W. similis Mills	–	12	–	–	–	–	–	25	–	–	–	–	–	–	–	–	–	3	2
W. sp. #1	15	18	–	–	–	–	–	25	–	13	–	–	20	–	–	–	–	8	5
Xenylla duchesnea Wray	23	–	20	–	–	–	–	–	56	63	25	50	40	50	–	–	14	22	9
ONYCHIURIDAE																			
Onychiurus affinis Ågren	–	–	–	–	–	–	–	–	11	–	–	–	–	–	–	–	–	1	1
O. parviconnis Mills	–	–	–	–	–	25	–	–	44	25	–	–	–	–	–	–	–	7	3
O. pseudarmatus Folsom	–	–	–	–	–	–	–	–	11	–	–	–	–	–	–	–	–	1	1
O. pseudofimetarius Folsom	–	–	–	–	–	–	–	–	–	–	25	–	–	–	–	–	–	1	1
O. ramosus Folsom	–	–	–	–	–	–	–	–	–	–	–	17	–	–	–	–	–	1	1
O. reluctus Christiansen	23	35	40	–	–	–	–	25	–	25	25	17	–	50	–	–	29	19	9
O. similis Folsom	–	–	–	–	–	–	–	–	–	–	–	17	–	–	–	–	–	1	1
O. talus C. & B.	–	–	–	–	–	–	–	–	11	–	–	–	–	–	–	–	–	1	1
O. sp. #1	–	–	–	–	–	25	–	–	33	25	50	–	40	50	–	–	–	11	6
O. sp. #2	–	–	–	–	–	–	–	–	44	13	–	–	–	–	–	–	–	5	2
O. sp. #3	8	–	–	–	–	–	–	–	56	63	25	50	–	–	–	–	–	15	5
Tullbergia callis Bacon	–	–	–	–	–	–	–	–	–	–	–	–	20	–	–	–	–	1	1
T. granulata Mills	18	–	–	–	–	–	–	–	11	13	–	–	–	–	–	–	–	3	3
T. hades C. & B.	–	–	–	–	–	–	–	–	11	–	–	–	–	–	–	–	–	1	1
T. lawensis Mills	15	18	20	–	–	–	50	50	22	50	25	17	40	100	–	50	14	24	13
T. macrochaeta (Rusek)	–	12	20	–	–	25	25	25	44	63	100	17	60	50	–	50	29	27	13
T. mala C. & B.	77	76	60	33	–	75	75	50	89	100	100	50	40	100	50	50	29	67	16
T. pacifica (Rusek)	8	18	20	33	67	25	–	25	22	63	–	50	40	–	–	50	29	25	13
T. tuseki C. & B.	15	12	–	–	–	–	–	–	44	63	50	–	60	50	50	–	57	25	9
T. yosii Rusek	8	6	–	–	–	–	–	–	11	–	–	17	–	–	–	–	–	4	4
T. sp. #1	–	–	–	–	–	–	–	–	11	50	–	–	–	–	–	–	–	5	2

above-ground vegetation and feed on living plant material (Christiansen 1964); those individuals appearing in our litter and soil samples included a large number of immatures. The low number of hypogastrurid species may be a consequence of the strong dominance of single species of Hypogastruridae in some wet meadow sites.

The two non-native grassland habitat types, the seeded grasslands and road-

ISOTOMIDAE																			
Anurophorus septentrionalis Pal.	31	35	20	-	33	-	-	-	22	13	-	17	-	50	-	-	-	16	7
Cryptopygus exilis (Gisin)	-	-	-	-	-	25	-	-	11	13	25	-	-	-	-	-	-	4	4
C. thermophilus (Axelson)	-	6	-	-	-	-	-	25	-	13	-	-	-	-	-	-	14	4	4
Folsomia decaxiopthalma Ford	38	41	60	-	-	-	25	75	22	38	50	33	20	-	-	-		30	10
F. macroseta Ford	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	1	1
F. nivalis (Packard)	23	12	-	-	-	25	25	-	89	75	50	33	40	-	-	-	-	27	9
F. onychiurina (Denis)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	-	1	1
F. stella C. & T.	8	6	40	-	-	-	-	-	78	75	75	33	20	50	-	-	14	24	9
Folsomides americanus Denis	15	29	60	-	-	75	25	25	100	100	75	100	40	-	-	-	100	50	12
F. decemoculatus Mills	-	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	1	1
Isotoma caeruleatra Guthrie	-	-	-	-	-	25	50	-	67	63	-	50	20	-	-	-	-	18	6
I. notabilis Schäffer	-	6	-	-	-	25	-	-	78	100	50	33	60	-	-	-	43	27	8
I. tuckeri C. & B.	-	-	-	-	-	-	-	-	33	-	25	17	-	-	-	-	14	6	4
I. viridis Bourlet	-	-	20	-	-	-	25	-	67	25	-	17	40	50	-	-	-	14	7
Isotomiella minor (Schäffer)	-	-	-	-	-	50	-	-	89	38	50	-	20	-	-	-	14	17	6
Isotomodes fiscus C. & B.	46	24	40	-	-	-	-	25	11	-	-	17	40	50	-	-	-	18	8
Isotomurus palustroides Folsom	-	-	-	-	-	25	-	-	-	-	25	-	-	-	-	-	-	2	2
Proisotoma dubia C. & B.	-	-	-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	3	1
P. minuta (Tullberg)	-	6	20	-	-	25	-	25	33	38	25	17	20	50	-	50	43	18	12
P. vesiculata Folsom	-	-	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	2	1
P. sp. #1	-	-	-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	3	1
ENTOMOBRYIDAE																			
Entomobrya assuta Folsom	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	3	2
E. confusa Christiansen	-	-	-	-	-	-	-	-	100	50	25	50	20	50	-	-	-	19	6
E. sabulicola Mills	-	-	-	33	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Lepidocyrtus cyaneus Tullberg	-	-	20	-	-	50	25	-	44	25	50	-	20	-	-	-	29	15	7
L. violaceus Fourcroy	-	-	20	-	-	-	-	-	22	13	50	-	40	-	-	-	-	8	5
Pseudosinella octopunctata Börner	-	-	40	-	-	-	50	50	33	63	25	83	80	-	-	-	71	29	9
P. violenta (Folsom)	-	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	14	2	2
Seira bipunctata (Packard)	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Willowsia buski (Lubbock)	22	-	-	33	-	-	-	-	11	-	-	-	-	-	-	-	-	4	4
W. nigromaculata (Lubbock)	11	13	-	33	-	-	-	-	11	13	25	-	-	-	-	50	-	7	7
NEELIDAE																			
Neelus incertus (Börner)	-	-	-	-	-	-	-	-	11	-	-	-	20	-	-	-	-	2	2
SMINTHURIDAE																			
Arrhopalites benitus (Folsom)	-	-	-	-	-	-	-	-	56	25	25	-	-	-	-	-	-	8	3
A. caecus (Tullberg)	-	-	-	-	-	50	-	-	11	13	75	-	-	-	-	-	-	7	4
Bourletiella wexfordensis (Snider)	-	18	40	-	-	25	-	-	11	13	-	17	20	-	-	-	-	10	7
Dicyrtoma marmorata (Packard)	-	-	-	-	-	-	-	-	-	13	25	-	-	-	-	-	-	2	2
Sminthurinus elegans (Fitch)	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	1	1
Sminthurus medialis Mills	-	-	-	-	-	25	-	-	-	13	-	17	-	-	-	-	-	3	3
Total species (76)	23	27	21	7	4	20	13	16	49	44	33	35	31	16	6	9	23		

* = Percentage of sites of the habitat type occupied.

Table 3. Number of Collembola species by habitat type.

HABITAT	Number of Species/Site Mean ($\bar{x}$)	Standard deviation (s)	Total species/ habitat type
GRASSLAND			
Ridge and Steep Slope	5.0	(3.0)	23
Gentle Slope	5.0	(3.5)	27
Shrubby Grassland	7.0	(4.4)	21
Claypan	2.7	(2.4)	7
Saline Lowland	2.0	(0.8)	4
Wet Meadow	7.5	(2.6)	20
Seeded Grassland	4.5	(1.7)	13
Roadside Ditch	6.3	(3.4)	16
FOREST			
Upland Deciduous Forest	19.4	(3.5)	49
Wooded Draw	16.9	(3.0)	44
Riverbottom Forest	14.0	(1.6)	33
Coniferous Forest	11.2	(4.5)	35
Shelterbelt, Farmstead	10.6	(2.9)	31
MISC.			
Stripmine Spoils	10.0	(1.0)	16
Badlands	2.5	(1.9)	6
River Sandbar	4.5	(2.5)	9
Cultivated Field	7.3	(1.8)	23

side ditches, had faunas comprised mainly of species widespread in both forest and grassland habitats. Fewer species were found in the non-native sites, but this was probably affected by the smaller number of sites sampled and may not represent a true difference in species diversity.

Forested areas had the greatest variety of collembolans (Tables 2 and 3). Higher soil moisture and a greater variety of microhabitats (litter, leaf mold, humus, mineral soil) are likely reasons for this trend. Twenty-one species were found only in forest habitats; many others showed a strong preference for such sites. Fourteen species occurred in all forest habitats; in contrast, not one species of collembolan occurred in all grassland habitats. *Isotomiella minor* was frequent in deciduous wooded areas (which tended to have a significant humas layer) but was found in none of the coniferous sites, and only occasional specimens occurred in shelterbelts. This is in accord with the work of Poole (1961), who reported that *I. minor* was largely restricted to humus, with low occurrence in litter. In contrast, he found *Isotoma notabilis* to be more common in litter than in humus; this species was abundant and widely distributed in our wooded sites.

Of species restricted to one or two habitat types, seven (*Onychiurus affinis, O. pseudarmatus, O. talus, Tullbergia hades, Neanura muscorum, Folsomia*

decemoculata, and *Proisotoma vesiculata*) appeared only in upland deciduous forests; others extended to wooded draws and/or shelterbelts (Table 2). Upland deciduous forests had the greatest variety of species, 49, while wooded draws and 44 species (Tables 2 and 3).

While upland deciduous forests and wooded draws had similar species, a comparison of the abundance of some shared species shows that the fauna of wooded draws is not simply an "impoverished" version of the upland deciduous forest fauna. Certain species, including *Folsomia decaxiopthalma, Odontella bayeri, Proisotoma minuta, Pseudosinella octopunctata,* and *Tullbergia macrochaeta* were more abundant in wooded draws than in upland forests, while the reverse was true for *Folsomia nivalis, Isotoma notabilis, Isotomiella minor*, and *Odontella armata*.

Riverbottom forest was the sole habitat type for *Onychiurus pseudofimetarius*, found at only one site. *Isotomurus palustroides* occurred at that site and in one wet meadow, and *Friesea pentacantha* was also found at that site and in three wet meadows. *Arrhopalites caecus* occurred in three riverbottom forests and two wet meadows. The riverbottom forest site having the above species had a poorly drained clay soil and was subject to frequent flooding; its moisture situation was similar to that of a wet meadow. The other riverbottom forest sites, which were less frequently flooded, had many species in common with upland deciduous forests and wooded draws.

Of the forest habitats, coniferous forests were the most likely to have species that were restricted only to that habitat type and often to one or two sites. *Onychiurus ramosus* and *Willemia dubia* were found only in a relatively dense ponderosa pine forest. *Folsomia macroseta* occurred only in a more open ponderosa pine site. *Proisotoma dubia* and an undescribed species of *Proisotoma* were found in three coniferous sites each (Table 2). No species was found that was entirely restricted to either the juniper sites or the limber pine sites.

Shelterbelts generally had species similar to those of other deciduous wooded sites, but the distribution of those species was varied. *Pseudosinella octopunctata* was the only species that occurred in more than three of the shelterbelts. The only specimen of *Tullbergia collis* was found in a shelterbelt, as was the single specimen of *Sminthurinus elegans* (Table 2). Shelterbelts had the fewest species of the five forest sites, but they had more species than any of the grassland or miscellaneous sites (Tables 2 and 3).

The miscellaneous sites, as expected, were variable in species composition. The two stripmine spoils had only three species in common. Of the 16 species, all but five also occurred in samples from cultivated fields, and all but two were found in at least one shelterbelt, suggesting that these species may be associated with disturbance. However, there was less similarity with the faunas of seeded grasslands or roadside ditches, habitats that are also subject to disturbance. None of the species was unique to stripmined land.

Samples from the badlands sites yielded only six species, most of which were widespread in habitat preference. This habitat type had one of the lowest values calculated for mean species number (Table 3).

The two river sandbar sites yielded nine species, of which seven occurred at a single site, including the only record of *Folsomia onychiurina*.

Most of the species found in cultivated fields were cosmopolitan, occurring in both grassland and forest sites. All but five of the 23 species were present in shelterbelts also. The absence of Sminthuridae (Table 2) may have been influenced by the lack of vegetative cover. Some species of sminthurids are reported to be pests in alfalfa fields (Maynard 1951); the proportion of sminthurids may have been different if samples had been taken from fields in which crops were dense. Wallwork (1976) suggests that species diversity of soil fauna may be reduced by agricultural pesticides. The average number of species per site was higher for cultivated fields than for prairie grasslands (Table 3), but a more informative comparison would be to compare our values with those for similar cultivated fields on which no pesticides were used.

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